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Neurobiology

Thinking about thoughts: how the brain evaluates confidence

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Confidence and uncertainty in our thoughts are extremely important when making decisions, but how does the brain compute confidence? We found a region in the brain closely associated with confidence. This sheds light on how the brain evaluates our own thoughts and actions.

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Do you want to marry your partner? Do you want to quit your job? And perhaps more importantly, how sure are you about it? Even for "yes or no" questions, our decisions cannot be reduced to black or white. Decisions always come with a sense of confidence or uncertainty, a belief of whether we are making the right choice, a reflection about our own actions and thoughts. This confidence in our decisions is key for us to eventually decide one way or another. Confidence is also essential to learn from experience, to make plans, and to guide our actions towards a specific goal.

Unfortunately, not everybody can use their confidence to appropriately guide behavior. For example, patients with obsessive-compulsive disorder (OCD), a neuropsychiatric disorder that affects 1-2% of adults, have a different relationship between confidence and choice. These patients can compute a sense of confidence, but they cannot use these beliefs to guide their actions. This leads to strange behavior, such as compulsively washing their hands, even though they know they are clean, or repeatedly checking whether the door is closed.

According to some philosophers, humans are the only beings that tend to think about thinking, even though we do not always do so. The capacity to think about thinking is called metacognition, and confidence is a simple form of metacognition that can be experimentally tested in a laboratory setting. In fact, it is so simple that even some animals such as macaques and rats have been shown to have a sense of confidence that guides their behavior. Thinking about thinking may thus not be so specific for humans after all! Putting ontological questions aside, the first scientific approach to confidence dates to the pragmatist philosopher and scientist Charles Sanders Peirce in the late 19th century, a forerunner of modern cognitive science. Confidence research has since then had a long tradition in experimental psychology, however, neuroscientists only recently started to investigate its neural mechanisms.

We can study the brain by implanting electrodes directly into the brain of patients. This is usually done by doctors to diagnose epilepsy. This technique is designed to find the origin of the seizures, but also provides an opportunity to measure the activity of single neurons. Since these patients must stay for several days in the hospital, neuroscientists can use these electrodes to research how the brain works, if the patients agree to perform cognitive experiments during their hospital stay. However, because this method is very invasive, these electrodes are solely implanted for medical reasons. These electrodes allow neuroscientists to directly measure the electric discharges of single neurons, called action potentials, which are the language in which neurons talk to each other. Thanks to the kind collaboration of our patients, we could make use of these electrodes to study the neural mechanisms of confidence at a more detailed scale than ever before.

We analyzed the activity of hundreds of neurons during cognitive experiments, and we found neurons whose activity correlated with the patients' reports of confidence in the region of the brain called the medial temporal lobe. This region lies deep inside the brain and is associated with many cognitive functions like memory, emotions and decision making. When a patient reported a low confidence, we found neurons that fired a low number of action potentials, and the higher the confidence reported during the experiments, the more action potentials these neurons fired. This rate of action potentials, called firing rate, forms a neural code for the confidence level during decisions. Moreover, the activity of these neurons was persistently influenced by confidence levels for a long period of time that lasted several seconds and stopped abruptly after the information was no longer relevant for the task at hand. Our findings suggest that these neurons maintained the confidence estimate by means of their firing rates, as an active mechanism of memory storage, and this information was discarded once no longer needed.

Altogether our results suggest that the medial temporal lobe plays a key role in the computation of confidence and in its short-term storage. This is important since the medial temporal lobe is affected in several neuropsychiatric disorders, such as dementia, epilepsy, or limbic encephalitis. Our research may therefore help understand how these diseases work. More generally, we have started to shed light on the neuronal mechanisms for how we think about our own thoughts. Next time you are unsure about an important decision (like what to eat for dinner), you can blame your medial temporal lobe!